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(54) Ink jet printer with improved printhead cooling system

(57) Printhead temperatures are maintained at an optimum temperature by mounting the printheads (52A, 54A,56A,58A)in thermal contact with a support bar (46,48,50) through which an interior channel (46A,48A, 50A) has been formed. A cooling medium such as water is circulated through the channel (46A,48A,50A), the circulating medium absorbing heat generated by the printhead during operation. In one partial width array embodiment, support bars (46,48,50) are mounted at each end to hollow frame members (42,44). Channels (46A,48A, 50A) are formed through the length of the bars (46,48,50) which connect into the interior of the frame members (42,44). Water introduced via a pump/circulation mechanism (62,64) enters the entrance port of one frame member (42), circulates through the bar channel (46A,48A,50A), and exits the other frame member (44) through an exit port. Recirculation is achieved using a feedback loop between a water reservoir (64) and a pump (62). In another embodiment, a plurality of printhead modules (72A) are butted together on a single cooling support bar (73) having a channel therethrough through which water is circulated.

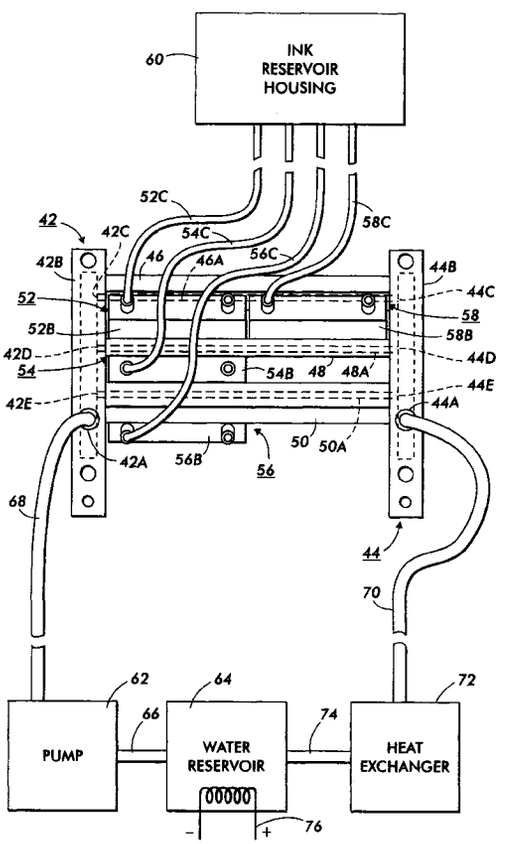

FIG. 3

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Description

The present invention relates to ink jet printing, and more particularly to a system for cooling ink jet printheads during operation to maintain the printhead at an optimum temperature.

Conventionally, most commercial ink jet printers are of the partial width array scanning type wherein a printhead module, typically one inch in width and containing a plurality of ink ejecting nozzles or jets, is mounted on a carriage which is moved in a scanning direction perpendicular to the path of motion of a recording medium such as paper. The printhead is in fluid communication with an ink supply cartridge. After each line scan by the printhead, the recording medium is advanced, and the printhead is scanned again across the medium. A black only scanning printer is disclosed, for example, in U.S. Patent 5,136,305. For color printing, additional printhead modules and associated color ink jet cartridges are added to form a printer configuration of the type, for example, disclosed in 5,099,256.

Pagewidth ink jet printers are known in the art which utilize one or more full pagewidth array printbars. In these pagewidth printers, a printbar is fixed in position adjacent to the path of the recording medium. Since there is no scan and re-scan time, a much higher print speed (on the order of 10:1) is enabled. One full width print bar may be used for a black only system; additional full width color printbars may be added to enable a highlight or full color printer.

One known problem, with both partial and full width thermal ink jet printers, is the degradation in the output print quality due to increased volume of ink ejected at the printhead nozzles resulting from fluctuations of printhead temperatures. These temperatures produce variations in the size of the ejected drops which result in the degraded print quality. The size of ejected drops varies with printhead temperature because two properties that control the size of the drops vary with printhead temperature: the viscosity of the ink and the amount of ink vaporized by a firing resistor when driven with a printing pulse. Printhead temperature fluctuations commonly occur during printer startup, during changes in ambient temperature, and when the printer output varies.

When printing text in black and white, the darkness of the print varies with printhead temperature because the darkness depends on the size of the ejected drops. When printing gray-scale images, the contrast of the image also varies with printhead temperature because the contrast depends on the size of the ejected drops. When printing color images, the printed color varies with printhead temperature because the printed color depends on the size of all the primary color drops that create the printed color. If the printhead temperature varies from one primary color nozzle to another, the size of drops ejected from one primary color nozzle will differ from the size of the drops ejected from another primary color nozzle. The resulting printed color will differ from the intended color. When all the nozzles of the printhead have the same temperature but the printhead temperature increases or decreases as the page is printed, the colors at the top of the page will differ from the colors at the bottom of the page. To print text, graphics, or images of the highest quality, the printhead temperature must remain constant.

Various printhead temperature controlling systems and methods are known in the prior art for sensing printhead temperature and using sensed temperature signals to compensate for temperature fluctuations or increases.

U.S. Patent 5,220,345 discloses a printhead temperature control system which places a plurality of temperature detectors at different positions and monitors the temperature differences to control ink supplied to the associated ink channels.

U.S. Patent 5,168,284 discloses a closed loop system which produces non-printing pulses in response to a difference between a reference temperature signal and printhead temperature signals produced by a temperature sensor located on the printhead.

U.S. Patent 5,223,853 to Wysocki et al. discloses a method of controlling the spot sizes printed by a thermal ink jet printer. The temperature of the ink in the printhead is sensed and a combination of power level and time duration of the electrical input signal to the heating elements is selected by entering the sensed temperature of the ink into a predetermined function relating to the energy of the input signal to the corresponding resulting size of the spot on the copy sheet.

U.S. Patent 5,017,941 discloses a printhead which is cooled by circulating a cooling medium through passageways formed in the printhead.

Maintaining a printhead temperature at a constant level by use of a cooling medium such as air or a fluid is an attractive and inexpensive technique, dispensing with the need for temperature monitoring circuits. Blowers are, however, an additional expense and modifying a printhead to circulate a cooling fluid therethrough as described in the '941 patent presents additional fabrication problems and expense.

It is therefore one object of the invention to provide an inexpensive thermal cooling of an ink jet printhead during a print operation.

It is a further object to provide a cooling means for circulating cooling medium which does not require modification of the printhead.

According to the present invention there is provided an ink jet printer including at least one printhead which is energised to cause expulsion of ink droplets through printhead nozzles onto a recording medium, the at least one printhead having a printhead cooling system comprising:

a cooling support bar having a channel formed therethrough, the printhead being mounted in thermal contact with said support bar and

means for continuously circulating a cooling medium through said support bar channel, wherein heat generated by the printhead during print operation is thermally transferred to the medium circulating through the support bar.

In one embodiment, partial width printheads form a scanning printhead assembly and are maintained at an optimum operating temperature by circulating cooling fluid from a common reservoir source through channels formed in cooling support members to which the printheads are secured.

In another embodiment, partial width array chips are abutted together to form a full width printhead, and the printhead chips are mounted on a single cooling support member.

FIG. 1 illustrates a partial perspective view of a printer having a plurality of partial width array printheads movably mounted on a scanning carriage so as to scan across a curved surface of a paper holding drum.

FIG. 2 shows an end view of the printer of FIG. 1.

FIG. 3 shows a top view of the printer of FIG. 1, including ink reservoirs and water cooling and temperature control components.

FIG. 4 shows a top view of a full width printbar mounted on a single cooling support bar.

While the present invention will be described in connection with preferred embodiments thereof, it will be understood that it is not intended to limit the invention to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

FIG. 1 illustrates the cooling of a partial width array printhead assembly in a scanning architecture. As shown, a printing apparatus 10 includes a motor 11 connected to a suitable power supply (not shown) and arranged with an output shaft 14 parallel to an axis 15 of a cylindrical drum 16, preferably of aluminum construction, which is supported for rotation on bearings (not shown). A pulley 17 permits direct engagement of the output shaft 14, to a drive belt 18 for enabling the drum 16 to be continuously rotationally driven by the motor 11 in the direction of an arrow A at a predetermined rotational speed. The rotational speed is set to maximum determined by the firing logic (the number of jets and number fired at a time) and the maximum jet firing rate.

A recording medium 19, such as a sheet of paper or a transparency, is placed over an outer surface 20 of the drum 16, with a leading edge 21 attached to the surface 20 before printing to enable attachment of the sheet thereto either through the application of a vacuum through holes in the drum 16 (not shown) or through other means of holding such as electrostatic. As the drum 16 rotates, the sheet of paper 19 is moved past a printhead carriage 22 supported by a lead screw 24 arranged with the axis thereof parallel to the axis 15 of the drum 16 and supported by fixed bearings (not shown) which enable the carriage 22 to slidably translate axially. A carriage rail 23 provides further support for the carriage as the carriage moves in the direction of arrow 25 perpendicular to the moving direction of the sheet 19. A second motor 26, such as a stepper motor or other positioning mechanism, controlled by a controller 28, drives the lead screw with a second belt 29 connecting a clutch 30 and a clutch 31 attached to the lead screw 24 for movement thereof.

The printhead carriage supports a color printhead assembly 40, details of which are shown in FIGS. 1 - 3. Assembly 40 comprises two end frame members, 42, 44, to which are secured support bars 46, 48, 50. Bars 46 to 50 are arranged in an angular alignment with respect to center point C of drum 16 in a manner described below. Bars 46 to 50 are prearranged in an angular alignment and are of graphite in the preferred embodiment. A first partial width array printhead cartridge 52 (magenta) is secured to the side of bar 46; a second PWA color printhead cartridge 54 (cyan) is secured to bar 48, and a third color PWA printhead cartridge 56 (yellow) is secured to the side of bar 50. A fourth PWA printhead cartridge 58 (black) is also secured to the side of bar 46. All of the printheads assume the same angular orientation as the bars to which they are secured.

Printed wiring boards (not shown) contain circuitry required to interface and cause the individual heating elements (not shown) in the subunits to eject ink droplets from the nozzles. While not shown in FIG. 1, the printed wiring boards are connected to individual contacts contained on the subunits via a commonly known wire bonding technique. The bit mapped image data required to drive the individual heating elements of the printhead subunits is supplied from an external system by a standard printer interface, modified and/or buffered by a controller 42 and transferred to the printheads by ribbon cables (not shown) attached thereto.

Each printhead cartridge comprises a printhead fluidly connected to an ink tank. The cartridge 52 comprises a printhead 52A connected to ink tank 52B. Cartridge 54 comprises a printhead 54A connected to ink tank 54B. Cartridge 56 comprises a printhead 56A connected to ink tank 56B and cartridge 58 comprises a printhead 58A (not visible) connected to cartridge 58B. The ink tanks are connected by flexible supply lines 52C, 54C, 56C, 58C to separate sections of an ink supply reservoir 60.

The cooling system for cooling printheads for 52A to 58A will now be described, with reference to FIG. 3, As shown in FIG. 3, frame member 42 has a port 42A which connects to an interior chamber 42B. At the bottom of chamber 42B, exit ports 42C, 42D and 42E connect into the entrance ends of channels 46A, 48A, 50A formed, respectively, through the length of bars 46, 48, 50. Frame member 44 has a port 44A connecting to an internal chamber 44B. At the bottom of chamber 44B, exit ports 44C, 44D and 44E connect with the exit ends of channels 46A, 48A, and 50A.

A pump 62 is connected to a water reservoir 64. Tube 66 connects the water to the pump and tube 68 connects water from the pump into chamber 42B via port 42A. Tube 70 is connected between port 44A and a heat exchanger 72 to reservoir 64 via tubing 74. (Head exchanger 72 may not be needed if the duty cycle of the printing system is very low.) Optionally, an immersible reservoir heater 76 is placed within reservoir 64 to increase and maintain the reservoir temperature at several degrees above ambient to minimize variations in nominal spot size of ejected ink droplets. Maintaining the temperature 5-8°C above ambient also significantly improves the heat transfer rate of the system, therefore, requiring a smaller heat exchanger.

In operation, the carriage under control of the system controller carries the printhead assembly along the scan path forming color images in a known manner on the recording medium 19. The sheet 19 is advanced following each print scan. As operation continues, the printhead tends to overheat. However, because of the cooling system in place, water is continuously circulated through the supply bars, the water absorbing heat from the printheads, providing a cooling effect and maintaining the printhead in optimum temperature.

FIG. 4 shows a second embodiment of the invention wherein a printer 70 includes a full width black printbar 72 positioned to write on a recording medium 74 which is indexed by a motor (not shown) and moves in the direction of arrow 76. Printbar 72 has been assembled from a plurality of printhead modules 72A which have been butted together and secured on support bar 73 to form a 12" printbar according to the techniques described, for example, in U.S. 5,221,397, whose contents are hereby incorporated by reference. Printbar 72, in this embodiment, provides 7,200 nozzles or jets. As described in the '397 patent, the printbar modules 72A are formed by butting together a channel array containing arrays of recesses that are used as sets of channels and associated ink reservoirs and a heater wafer containing heater elements and addressing circuitry. The bonded wafers are diced to form the printbar resulting in formation of the jets, each nozzle or jet associated with a channel with a heater therein. The heaters are selectively energized by input data sent from controller 42 to heat the ink and expel an ink droplet from the associated jet. The ink channels are combined into a common ink manifold 78 mounted on the side of printbar 72 and in sealed communication with the ink inlets of the channel arrays through aligned openings. The manifold 78 is supplied with the appropriate ink, black for this embodiment, from an ink reservoir 80 via flexible tubing 82.

Support bar 73 has a channel 84 formed within the bar running along its entire length. The channel has an entrance port 73A and an exit port 73B. Pump 86 is connected to water reservoir 88. Tube 90 connects the water to the pump and tube 92 connects water from the pump into channel 84 via port 73A. Tube 94 is connected between port 73B and a heat exchanger 96 to reservoir 88 via tubing 98. An immersible reservoir heater 100 is again placed within reservoir 88 to increase and maintain the reservoir temperature at several degrees above ambient. As in the previous embodiment, during operation, water is continuously circulated through channel 84 in support bar 73 absorbing heat from the printhead during its passage. Test results demonstrate control of temperature across the printbar 72 by ± 2°C, and a reduction of the average steady state printhead temperature by as much as 22°C during an extended print run.

While FIG. 4 shows only a single black full width printer, it is understood that additional printbars can be added to produce a full color printer, each additional printbar being cooled by the same type of cooling mechanism.

While the invention has been disclosed in an embodiment wherein the images are formed on a curved image surface, the invention may be practiced in systems where the image is formed on a planar image surface.

Claims

1. An ink jet printer including at least one printhead (52A,54A,56A,58A) which is energized to cause expulsion of ink droplets through printhead nozzles onto a recording medium (19), the at least one printhead having a printhead cooling system comprising:

   a cooling support bar (46,48,50) having a channel (46A,48A,50A)formed therethrough, the printhead being mounted in thermal contact with said support bar and
   means (62,64) for continuously circulating a cooling medium through said support bar channel, wherein heat generated by the printhead during print operation is thermally transferred to the medium circulating through the support bar.

2. A printer according to claim 1, wherein the coolant circulating means comprises a cooling medium reservoir (64) and a pump (62).

3. A printer according to claim 2 further comprising a heat exchanger (72,96) connected between the cooling support bar and the cooling medium reservoir.

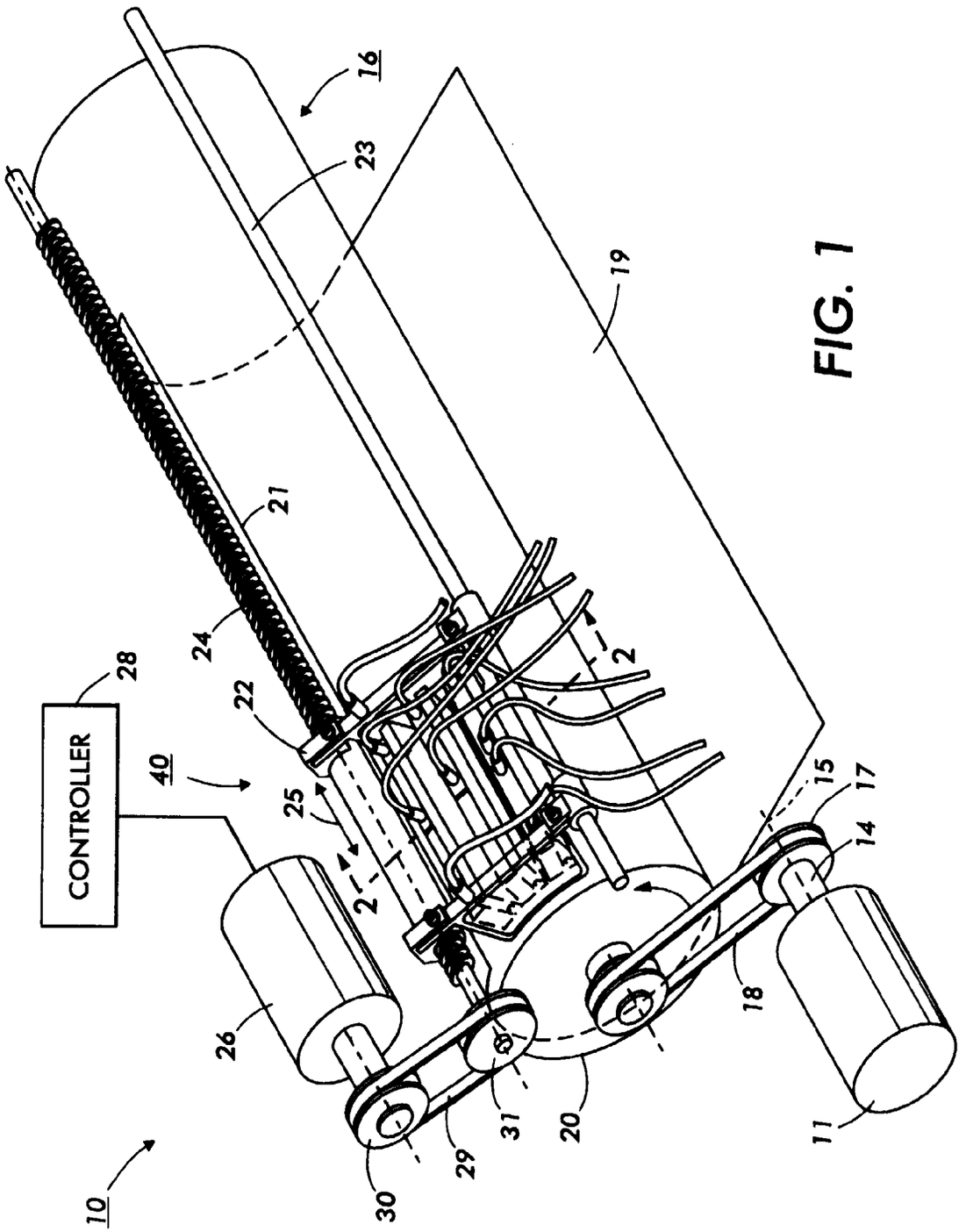
4. A printer according to claim 2 or 3, further comprising a heater (76) for increasing the temperature of the cooling medium and the cooling medium reservoir (64).

5. A printer according to any preceding claim further including a reciprocating carriage (22) and wherein

said cooling system comprises a plurality of support bars (46,48,50) mounted on said carriage, each support bar having a channel therethrough (46A, 48A,50A), each support bar having at least one printhead cartridge (52A,54A,56A,58A) mounted in thermal contact thereon, said cooling system further including first and second frame members (42,44) having a port (42A,44A) connecting to a chamber (42B,44B) interior to each frame member, the support bars being mounted to said frame members so that said channels terminate into said chambers, and wherein said means (62,64) for circulating a cooling medium is fluidly connected between said frame member ports so that the cooling medium flows in a closed loop through the entrance port of one frame member into the interior chamber of said frame members through the bar channels, and exiting the second frame member exit port and returning to the circulating means.

6. A printer according to claim 5 wherein three color printhead cartridges (52A,54A,56A) and a black cartridge (58A) are mounted on said support bars, and said printer further including means (60) for refilling said cartridges with ink of a selected color.

7. A printer according to any one of claims 1 to 4 wherein a plurality of printhead modules (72A) are butted together and mounted on at least one cooling support bar (73) to form a full width array printhead.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23
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22
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CONTROLLER
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11
10

FIG. 1

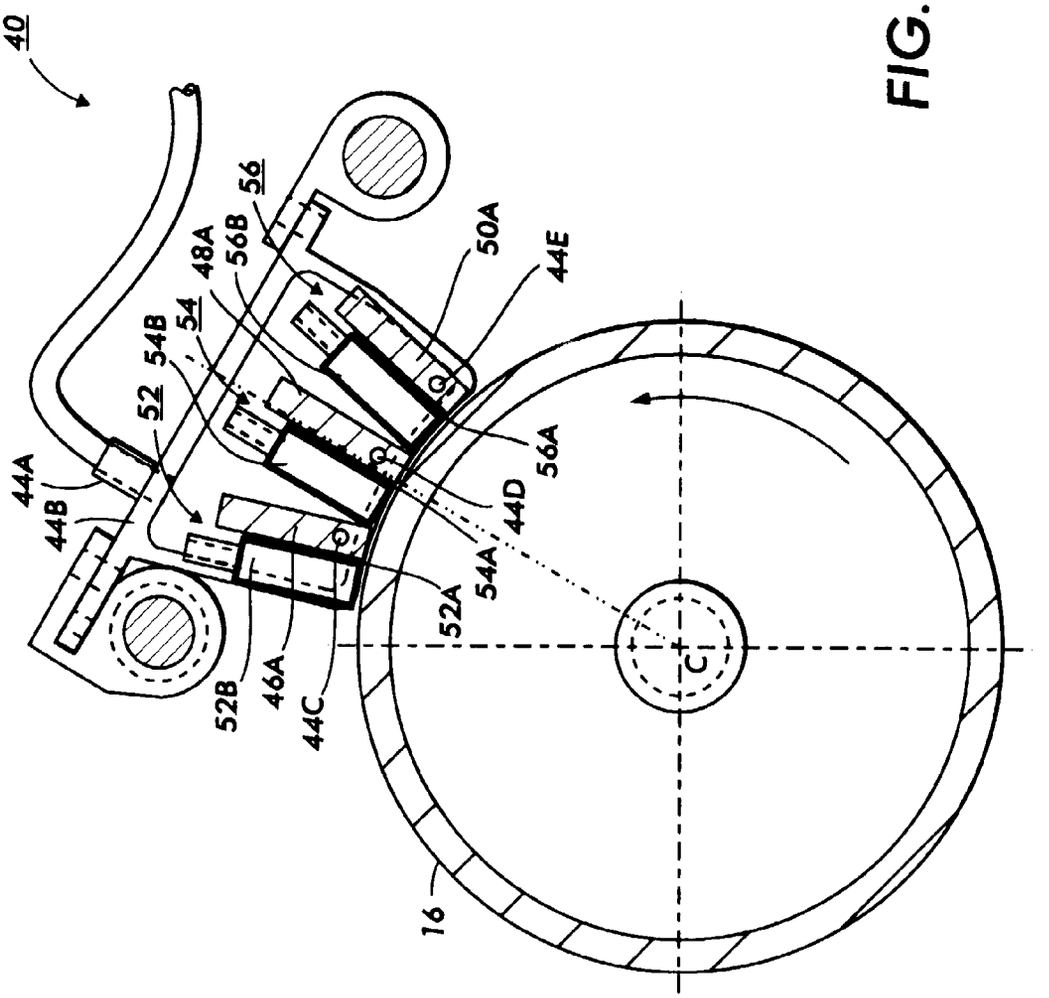
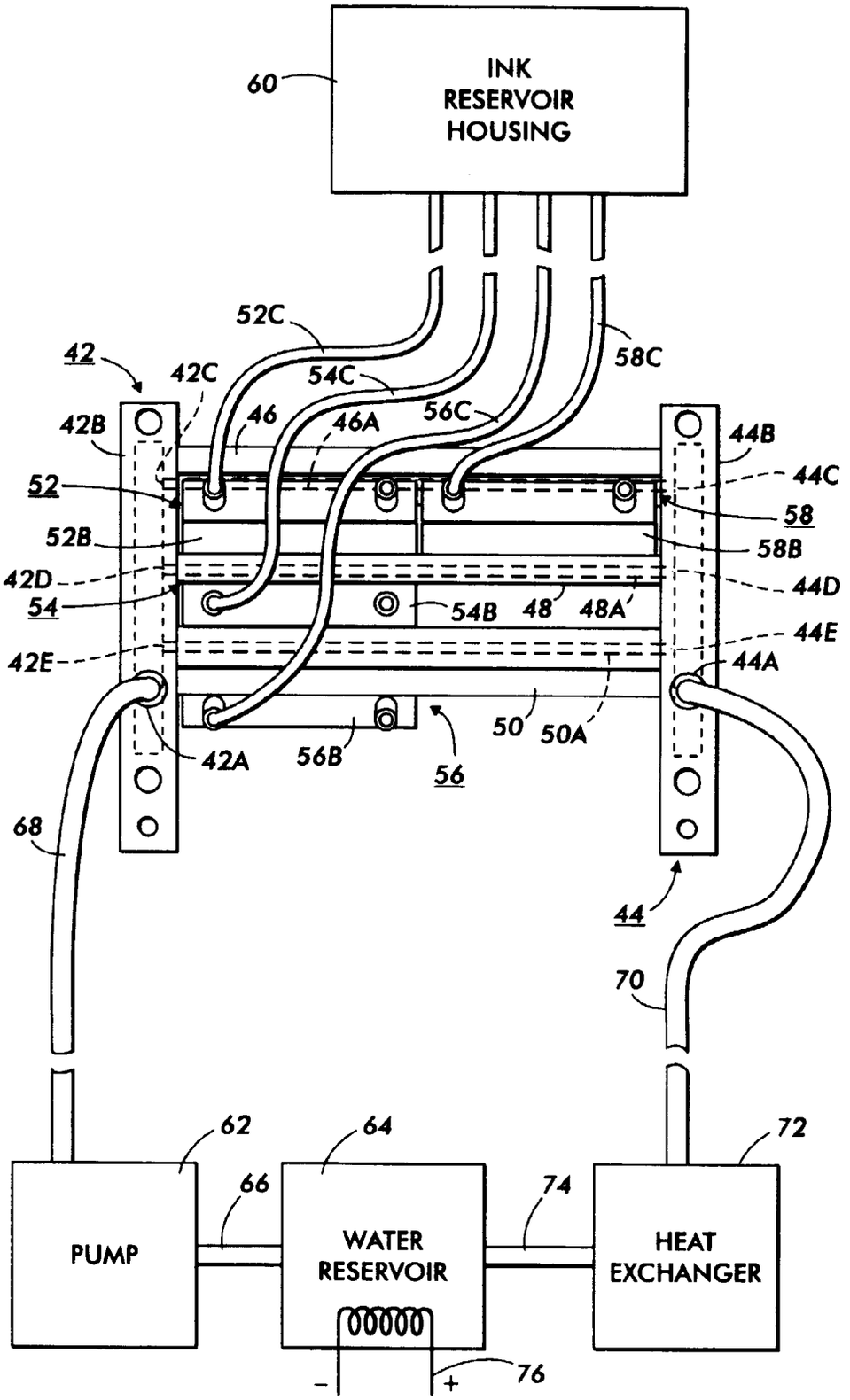

40
44A
44B
52
54B
54
48A
56B
56
50A
44E
56A
44D
54A
52A
52B
46A
44C
16
C

FIG. 2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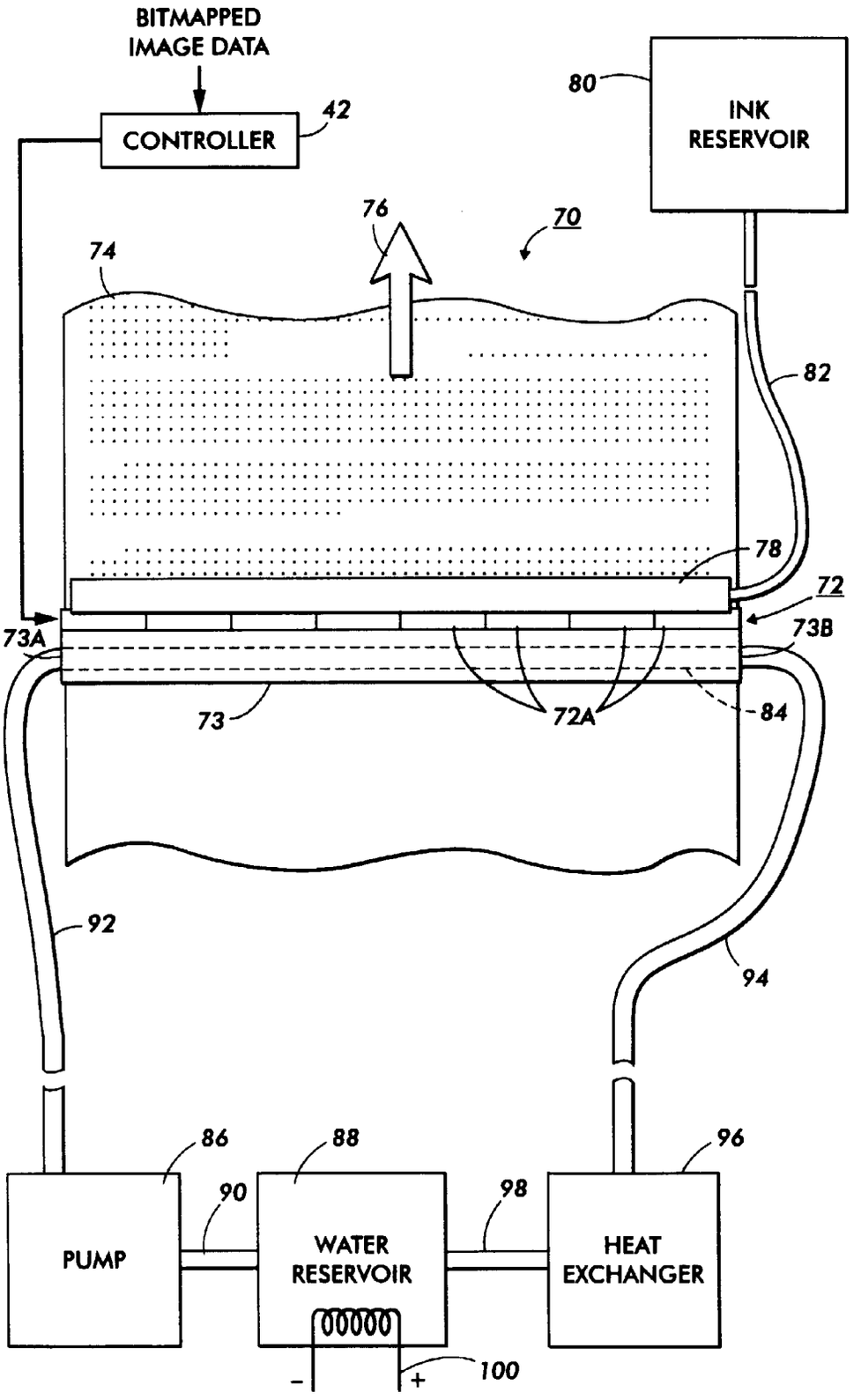
52C
54C
56C
58C
42
42C
42B
46
46A
44B
44C
52
58
52B
58B
42D
44D
54
54B
48
48A
44E
42E
44A
50
50A
42A
56B
56
68
44
70
62
64
72
66
74
PUMP
WATER RESERVOIR
HEAT EXCHANGER
76
-
+

FIG. 3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96
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98
PUMP
WATER
RESERVOIR
HEAT
EXCHANGER
100
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FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 0470

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X L	JP 08 207 272 A (XEROX) 13 August 1996 * the whole document * -& US 5 631 676 A (XEROX) 20 May 1997 * column 1, line 1 - line 25 * * column 2, line 38 - column 3, line 45 *	1-4,7	B41J29/377
X	EP 0 736 390 A (CANON KK) 9 October 1996 * column 7, line 48 - column 11, line 25; figure 5C *	1-6	
X	EP 0 450 641 A (CANON KK) 9 October 1991 * page 10, line 40 - line 42 * * page 15, line 52 - page 16, line 24 * * page 23, line 29 - page 25, line 42; figures 3,6,9 *	1,7	
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A	US 5 192 958 A (CHARNITSKI GEORGE A) 9 March 1993 * figure 2 *	5	
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 623 (M-1511), 17 November 1993 -& JP 05 193229 A (PFU LTD), 3 August 1993, * abstract *		
	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 June 1998	Van Oorschot, J

CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 0470

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 443 (M-1178), 12 November 1991 -& JP 03 187753 A (CANON INC), 15 August 1991, * abstract * -----		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

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